Local Study on the Correlation between Atmospheric Variables in Flash Flooding occurrences over Puerto Rico.

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Abstract

Forecasting in the Tropics is interesting as we face new challenges every day during the forecasting process. It is common every day in the tropics to consider a wide range of scenarios that can occur simultaneously on adjacent areas. Tropical weather varies dramatically making it a challenge for those dedicated to forecasting it. So with every challenge brought by tropical weather, we have to seek new ways on how we, as forecasters, predict the weather. New software, forecasting tools and studies are tested and implemented daily to improve our forecasts. Every day we take on the great responsibility of saving life and property regardless of the challenges. Due to this responsibility, every effort we make to improve our forecast leads us to better customer service, as lead time increases and false alarms diminish. In this paper, another tool is presented for forecasting flash flooding and it was written to raise awareness on flash flooding risk. The reader will have the opportunity to learn some of the hydrologic and orographic challenges which exist in Puerto Rico, compared to other Weather Forecast Offices (WFO).

1. Introduction

Every year, Puerto Rico is affected by numerous events of flooding. In some cases, flash flooding has caused severe damages to property and even fatalities. Flash flooding events in Puerto Rico are more common than we can imagine. On average, WFO San Juan issues around one hundred (100) flash flood warnings, for life-threatening conditions, per year in its County Warning Area (CWA). In addition, another five hundred (500) or so flood advisories, issued for flooding that falls short of life threatening conditions. The CWA lies between latitude 17.0^{o}N-19.5^{o}N and longitude 64.0^{o}W-68.0^{o}W. When a Flash Flood Warning is not issued, a flood statement may be necessary. When considering forecasting a flash flood one has to consider a series of variables. Most importantly, when these variables are combined one has to ask which values are needed in each variable to get flash flooding. The variables which will be considered in this paper are precipitable water, equivalent potential temperature at 700mb and wind direction and wind speed from 0 to 6 km.MSL (from the surface up to 500 mb. The variables will be defined in the next paragraphs.

Precipitable water (PWAT) is defined per NOAA Glossary as: *Measure of the depth of liquid water at the surface that would result after precipitating all of the water vapor in a vertical column over a given location, usually extending from the surface to 300 mb.* Meteorologists consider PWAT values to be extremely important since it tells them how much moisture is available to generate flooding rain. A normal value of PWAT in Puerto Rico is between 1.75 to 1.95 inches in the wet season, which runs from mid-April through November and between 1.30 to 1.60 inches during dry season which runs from December to early April (Fig. 1).

Another variable considered was equivalent potential temperature (Theta-E) at the 700mb level. From the NOAA glossary: Theta-E, which typically is expressed in degrees Kelvin, *is directly related to the amount of heat present in an air parcel. Thus, it is useful in diagnosing atmospheric instability.* Therefore as Theta-E increases, atmospheric conditions become favorable for rainfall to occur. Theta-E values at 700mb normally run between 315K to 320K in dry season and between 325-330K in summer.

Wind direction and wind speed is fundamental for: 1) convection to form; 2) and more importantly in a tropical island like Puerto Rico, where that convection will form. As forecasters, for us it is extremely important from which direction the wind will blow in a particular day and how strong it will be. For this reason, I chose the winds from the surface all the way up to 500 mb for this study. Although upper level winds are as important as the low to mid-level winds, in this case study I was particularly interested in knowing the direction and speed at these levels. Low level winds have a big influence since we have orographic lifting caused by the "Cordillera Central" of Puerto Rico which is a mountain range that extends from east to west in the middle of the island with maximum peak at near 4,300 ft. Most of the year, the dominant wind over the local islands are the trade winds with an east component most of the time. The final results of this study will be extremely important for meeting our primary goal of saving life and property.

2. Obtaining the Data

Flash Flood events for this case study were obtained using NOAA (National Oceanic and Atmospheric Administration) National Climatic Data Center (NCDC) Storm Events Data Base from October 2007 through December 2013. Only the most significant Flash flood events were selected. In addition, the Storm Data archive was used to obtain the Flash floods which were verified in our CWA. Precipitable Water (PWAT) data was obtained using the Sounding archive from the University Of Wyoming, Department of Atmospherics Science. The sounding data also runs from October 2007 through December 2013. The soundings used for this research were from TJSJ (San Juan, Puerto Rico). The wind data as well as Theta-E values were obtained also from the sounding archive, looking at the values observed from the Surface (1000mb) up to 6 km. (500mb).

3. Analysis and results

Forty-two (42) flash flood events and forty-two (42) non-flash flood events were taken in consideration for this study from October 2007 through December 2013. The forty-two flash flood events, were selected because they produced the most significant flash flooding having the biggest impacts over Puerto Rico . As we can see at Figure 2, May was the most active month in term of flash flood events with 11 events. May is a transitional month in our area between the dry season and wet season. The remaining months were evenly distributed with June been the second highest.

The 42 non-flash flood events were chosen from days prior to the occurrences of the aforementioned flash flooding events. The reason for selecting the non-flooding events prior to the flash flooding events is to find if a correlation between high PWAT values, high Theta-E values at 700mb and wind speed and wind direction with flash flooding occurrences exists, and compare it with the non-flash flooding event values.

3.1 Hydrology and orographic effects in flash flood potential

Which parts of Puerto Rico are at highest risk? Let's look into details checking all 42 flash flood events and separating all by forecast zones used in our office. (Figure 3.) As we look at Table 1, from the 42 cases, 22 were between North Central and Northeast sections of Puerto Rico. In fact, none of the cases fell over western Puerto Rico. Therefore, in summary the eastern half of Puerto Rico is at greatest risk of getting flash flooding.

Now that we have the flood prone areas identified, we need to know why these areas are susceptible for flash flooding. Looking in depth at these areas, we found very important hydrological and orographic aspects which enhance the shower development over these areas. Let's start with the Northeast section of Puerto Rico, and after, we will look the North-Central Puerto Rico.

Northeast Puerto Rico Basins

a) Basin Descriptions

From the Hydrologic Service Duty Manual: *The rivers of northeast Puerto Rico emanate from the Sierra De Luquillo Mountains which are dominated by the El Yunque rainforest (Figure 4). The major rivers are the Rio Espiritu Santo, Rio Mameyes, Rio Sabana, Rio Fajardo and Rio Blanco. There are numerous small, fast-moving and fast responding streams in this area due to the steep terrain gradients. Elevations range from over 3,000 feet to near sea level in mostly less than 10 miles.*

The main geographical feature that stands out from the northeast section of Puerto Rico is El Yunque rainforest. El Yunque, is located between the San Juan Metropolitan area and surrounding municipalities to the west and the eastern coastal municipalities. From the Hydrologic Service Duty Manual: *Annual rainfall in El Yunque is the highest in Puerto Rico, with annual estimates up to 180 inches in the highest areas and over 100 inches in a broad area surrounding this feature. Rainfall diminishes rather uniformly and rapidly toward the coast and portions of the coast south of Fajardo receive only around 50 inches per year. The land is densely vegetated in many areas.*

b) Flood Vulnerability

From the Hydrologic Service Duty Manual tell us how the rivers and streams in the northeast of Puerto Rico could lead to flash flooding: *These are extremely fast-responding and steep sloped streams with fairly small drainage areas. Channel slopes are among the highest in Puerto Rico. Contributing drainage areas are generally under 15 min, meaning time of concentration is very rapid. A mitigating effect is the* *extensive vegetation and high annual rainfall across the area that maintains high channel capacities.*

North-Central Puerto Rico Basins

a) Basin Descriptions

The majority of the main rivers from North-Central Puerto Rico are born in the mountains located in the central interior part of Puerto Rico. The most notable of these rivers are: Rio Grande De Arecibo (Figure 5), Rio Grande de Manatí and Rio La Plata.

Rio Grande De Arecibo Basin

a) Basin Description

From the Hydrologic Service Duty Manual: *The Rio Grande De Arecibo basin is located in the north central part of Puerto Rico about 30 miles west of the San Juan metropolitan area and includes portions of the municipalities of Arecibo, Adjuntas, Utuado and Jayuya.*

b) Flood Vulnerability

From the Hydrologic Service Duty Manual: *Historically, floods along the Rio Grande de Arecibo have significantly affected the urban areas of the city of Arecibo. Since 1899 there have been at least ten major floods in the area. The most severe in the modern history of the Rio Grande de Arecibo occurred on September 22, 1998, with the passage of Hurricane Georges. The flood caused widespread damage throughout the Rio Grande de Arecibo basin and had an estimated recurrence interval of more than 100 years at some locations.*

Rio Grande De Manati

a) Basin Description

The Rio Grande De Manatí originates in the mountains of central Puerto Rico at an elevation of about 2640 feet flowing generally northwest about 55 miles and discharges into the Atlantic Ocean about 35 miles west of San Juan (Figure 6). The watershed covers about 202 square miles at the mouth and is characterized by a narrow lower channel and a wide upper basin.

b) Flood Vulnerability

From the Hydrologic Service Duty Manual: *From All these streams in the upper basin have deeply dissected valleys with steep canyon walls which confine the flow during high water. However, there may be bridges or low water crossings on some streams which constitute the primary flood threat in these areas. A low water crossing over the Rio Toro*

Negro became the site of a flood fatality on the afternoon of October 12, 2004 when a vehicle trying to cross was washed downstream. There are likely other bridges or low water crossings which constitute the primary flood threat in these areas. The town of Orocovis located along the Rio Orocovis, is located in one of the few areas of the upper basin with a flood plain which is about 250 feet wide and a mile long in that area. The town of Ciales is located on high ground well above any flood threat. The relief of the basin below Ciales becomes much flatter, allowing the river to begin spreading out during floods.

Rio Cibuco

a) Basin Description

From the Hydrologic Service Duty Manual: *The Rio Cibuco and its principal tributary, the Rio Indio, have a total drainage area of about 107 square miles (Figure 7). The exact drainage area of these basins is indeterminate due to the karstic nature of the terrain. Rising in the northern foothills of Puerto Rico at an elevation of about 2000 feet, the Rio Cibuco flows northward and enters the Atlantic Ocean about 20 miles west of San Juan. The Rio Cibuco drainage area is confined between the expansive watersheds of the Rio Grande de Manati to the west and the Rio de la Plata to the east.*

b) **Flood Vulnerability**

From the Hydrologic Service Duty Manual: *Additional areas mentioned in this report and subject to possible flooding from the Rio Cibuco include the Cienaga Prieta and the Laguna Tortuguero. To the east of the Rio Cibuco coastal flood plain and east of the town of Ceiba, is the Cienaga Prieta which extends eastward for several miles and covers an area of about 1,500 acres. It is drained by a canal to the Rio Cibuco. In the Rio Cibuco and Indio flood plain, Highways 160, 647, 675, 676, 686, 687, 688, 689, and 690, as well as several unnumbered rural roads, are subject to flooding and the resulting disruption of traffic.*

Rio De La Plata

a) Basin Description

From the Hydrologic Service Duty Manual: *The drainage area of the Rio De La Plata covers around 241 square miles and resembles a boot in shape (Figure 8). It runs generally northwest through the municipalities of Cayey, Cidra, Comerio, Naranjito, Toa Alta, Toa Baja and Dorado for a total river distance of 63 miles; the longest in the island. It enters the Atlantic Ocean at a point 9 miles west of San Juan shortly after passing the urban centers of Toa Baja and Dorado.*

b) Flood Vulnerability

From the Hydrologic Service Duty Manual*: The basic causes of flooding in the basin are the same: large peak discharges resulting from torrential rains; the limited capacity of the existing channels and outlets; and in the area below Toa Alta, the low elevation of the land and the confining ridges along the coast. Encroachment in the floodways, inadequate bridge openings, sharp bends, shrubbery, debris and obstructions aggravate the flood hazard by restricting the passage of the flow. In addition the expansion of the San Juan metropolitan area into the La Plata basin exerts additional hydrologic stress.*

3.2 Precipitable water in predicting flash flooding

As stated in the introduction, precipitable water values are extremely important in forecasting big flood events. As forecasters, which PWAT values do we expect in Puerto Rico for active weather to occur? Looking at Figure 1, definitely, a PWAT value which is at two standard deviation over the mean value gives us high confidence in forecasting good chance of rainfall over our County Warning Area. This means high moisture content at the surface. Therefore, if we take in consideration that two standard deviation from the mean runs from 1.75 inches in January and peak to around 2.35 in August and September, everything that falls between those values or above, are enough to alert us that active weather could occur.

3.3 Theta-e values in forecasting flash flooding

Another important variable which is fundamental in forecasting flash flooding potential in the tropics is the Equivalent Potential Temperature (Theta-e) at 700mb. Why at 700 mb? It is at this level where most weather events occur, and during tropical season, it is where we can identify better Tropical Waves. Which Theta-e values at 700mb we look for active weather to occur? Values above 330K are considered high; this value means deep moisture extend through the mid-level of the atmosphere.

3.4 Wind flow from 0-6km in forecasting flash flooding

Whenever we speak about potential for flash flooding, the wind speed and wind direction must be taken in consideration. The wind direction is very important as our area dominated most of the year by the trade wind. Trade winds are defined per NOAA Glossary as: *Persistent tropical winds that blow from the subtropical high pressure centers towards the equatorial low.* Through most of the year these winds blow from the east or east southeast. During winter time, strong High Pressure systems over the North Central Atlantic, near Azores Islands, from December through March, produce a wind flow which is primarily from the east northeast. This east northeast wind flow brings to the local area passing showers to the north, and northeast sections of Puerto Rico. Meanwhile, during summer time, the aforementioned high pressure weakens and the weather pattern across the Caribbean promotes a more southeast wind flow, which is favorable for shower and thunderstorm development as this is a humid air as bring moisture from the deep tropics (Figure 9 and Figure 10). This flow combined with a synoptic weather feature, for example, tropical cyclones, the potential for flash flooding increases significantly.

One fundamental aspect which occurs over Puerto Rico is sea breeze/land breeze interaction. Sea breeze develops during the day, when land is warmer than the ocean and a thermal low pressure forms over land and High pressure over water. The circulation between these two areas, produce the sea breeze, which is the wind blowing from the ocean towards inland. At night, the process is reverse. That process is called land breeze, the wind inland moves offshore.

3.5 The perfect setup

Now that we have all the variables and we know exactly which values we need to have high risk of flash flooding, we have to ask ourselves what is a perfect setup for flash flooding to occur? Let's take a look first, at the 42 non-flash flood events. First, if we look at the precipitable water values during these 42 events prior to the occurrences of flash flooding, data analyzed through these events gave a precipitable water value mean of 1.83 inches with a standard deviation of 0.26 (Figure 11). Second, analyzing the Theta-e values at 700 mb through these events prior to flash flooding occurrence, we got a Theta-E value mean of 330K with a standard deviation of 5.31 (Figure 12). Finally, analyzing the 42 events prior to flash flood occurrence from this study, the mean wind flow below 500mb level was from the south-southeast (151 degrees) at 12 kts (Figure 13).

Now, let's take a look at the each variable but now during flash flood occurrences. Looking at the precipitable water values during these flash flood events, it was found that from the 42 events analyzed, 28 were at or above 2.0 inches (Table 2). Data analyzed gave a precipitable water value mean of 2.05 inches with a standard deviation of 0.25 (Figure 14). In the meantime, from the 42 events analyzed, 31 were between 330-340K, and from those 31, 20 were between 330-335K (Table 3). Data analyzed gave a Theta-E value mean of 333K with a standard deviation of 6.32 (Figure 15). In terms of winds, analyzing the 42 events from this study, the mean wind flow was from the south-southeast (156 degrees) during flash flood occurrences (Figure 16). Meanwhile, the mean wind speed was 13 kts (Figure 17).

After looking into the data, the events prior to flash flood occurrence and those where flash flooding occurred, we have significant difference mainly in the PW values and in Theta-E. Mean wind direction and speed were almost identical, however, frequency of those occurrences changed, with more east wind events during non-flash flooding compared to when flash flooding occurred. A comparison table showing the difference between both is summarized in Table 4.

As we saw, any combination of PWAT values of more than 2.00 inches, Theta-e values around 335 K, and a wind flow from the southeast to south-southeast around 13 kts, you will have a high risk of getting flash flooding. Normally, as the study revealed, if flash flooding doesn't occur then urban and small stream flooding are likely to occur somewhere in Puerto Rico. Definitely, such numbers force us to consider a high risk of at least some flooding over Puerto Rico whenever we get more than 2.0 inches in PWAT in the sounding. (Figure 18), which is the variable we give more weight for flash flood potential. However, although in term of numbers Theta-E values of 330K vs 333K doesn't look too big of a difference, in reality, for us it means a lot since it indicates a significant warming at 700mb, which results in instability. Remember, everything added to an already saturated atmosphere, will be enough to trigger flash flooding. Therefore, every increase or decrease on the aforementioned values, as much as PW and Theta-E will give favorable atmospheric conditions to get high intense rainfall which will result in flash flooding.

4. Social impacts

Flash flooding can affect many people over an extended area. It can threaten not only property but the lives of those who are situated at the affected area. Not being an exception, Puerto Rico has seen its share of important flash flooding. According to the Flood Safety Awareness page from NOAA, the most noticeable and historic events which affected Puerto Rico include the floods of October 6-7, 1985 better remembered as the Mameyes disaster; the Three King day Flash flood event on January 5-6, 1992 and flooding during Hurricane Hortense in September 9-10, 1996. Furthermore, according to the National Weather Service Performance Management site and the National Climatic Data Center (NCDC) storm events database, at least one flash flood event occurs annually in our CWA. From January 2008 through May 2014, 672 warnings have been issued across the County Warning Area (CWA). The month with more FFW's sent so far is May, with 135 warnings (Table 5).

It is estimated that from 1996 through 2013 the total property damage in Puerto Rico due to flash flooding has been 273 million dollars, taking in consideration that some damage data has not been reported (Table 6). Flash Flooding in Puerto Rico has been responsible from 1996-2013 for 35 estimated deaths (Table 7). On average, around 85 fatalities occured each year in the United States (Figure 19).

From those experiences we have learned that we are at risk of getting flash flooding at anytime, anywhere if the conditions are right. Hence, we need to take flash flooding as a serious threat and improve our ability to forecast it more accurately in areas like Puerto Rico where the weather is so variable.

5. Summary

A technical paper about the correlation between Precipitable water values (PWAT) Equivalent Potential Temperature at 700mb (THETAE) and wind flow between 0 to 6 km (Surface up to 500mb) in Flash Flooding occurrences over Puerto Rico was done. The first part consisted on determining the flash flood prone areas in order to let the forecaster know which areas are most susceptible for flash flooding in Puerto Rico. It was found the

Northeast and North Central sections of Puerto Rico are at biggest risk of getting flash flooding, when the aforementioned variable combined with topography and basin interaction to produced heavy rainfall. The variables were studied individually, to make clear which values are needed for flash flooding to occur. Then, a comparison was made between non-flash flood events and flash flood events to explore if a correlation exists. It was found; the perfect setup is when any combination of PWAT values of more than 2.00 inches, Theta-e values around 335 K, and a wind flow from the southeast to south-southeast around 13 kts, you will get a high risk of getting high intensity rainfall which will lead to flash flooding.

The paper ended with the social impacts which are for whom we work as forecasters. Our customers, the general public and ourselves are greatly affected by flash flooding when they occurred. A summary of property damage and fatalities were included to demonstrated the high risk of damage when flash flooding occurs and why is so important to check every possibility in order to improve our service and be able to meet our goal of safeguard life and property.

6. Acknowledgment

The author would like to acknowledge Gary Votaw, Science and Operations Officer at WFO San Juan for revising and helping me tremendously for his insights and ideas on the topic presented in this paper. In addition, wants to acknowledge Althea-Austin Smith, Senior Hydrologist at WFO San Juan, for giving me feedback on the hydrology aspect of Puerto Rico and Roberto García, Meteorologist in Charge for giving me the support needed to make this paper possible.

7. References

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NOAA Glossary [Available online at http://www.weather.gov/glossary]

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8. Tables and Figures

8.1 Figures

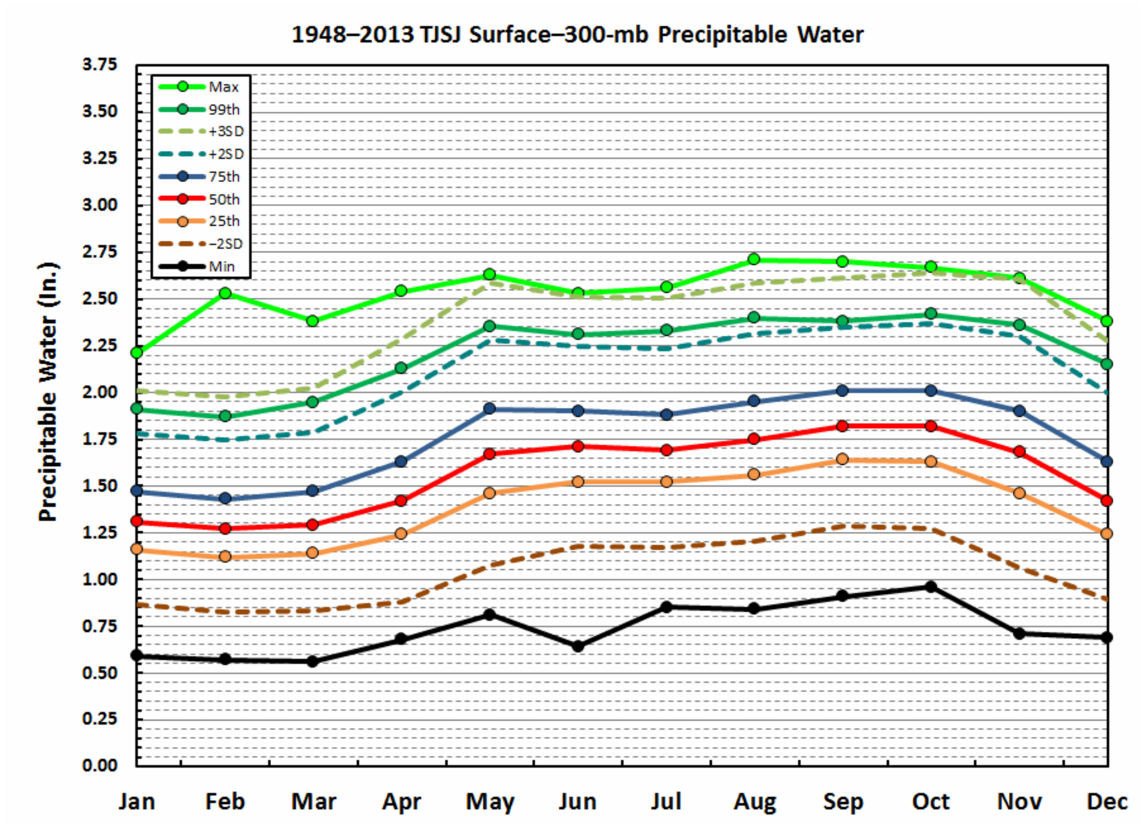

Figure 1. PWAT climatology for San Juan, PR(TJSJ). Figure was obtained from Upper-Air Climatology Plots, Rapid City, SD webpage at http://www.crh.noaa.gov/unr/?n=pw

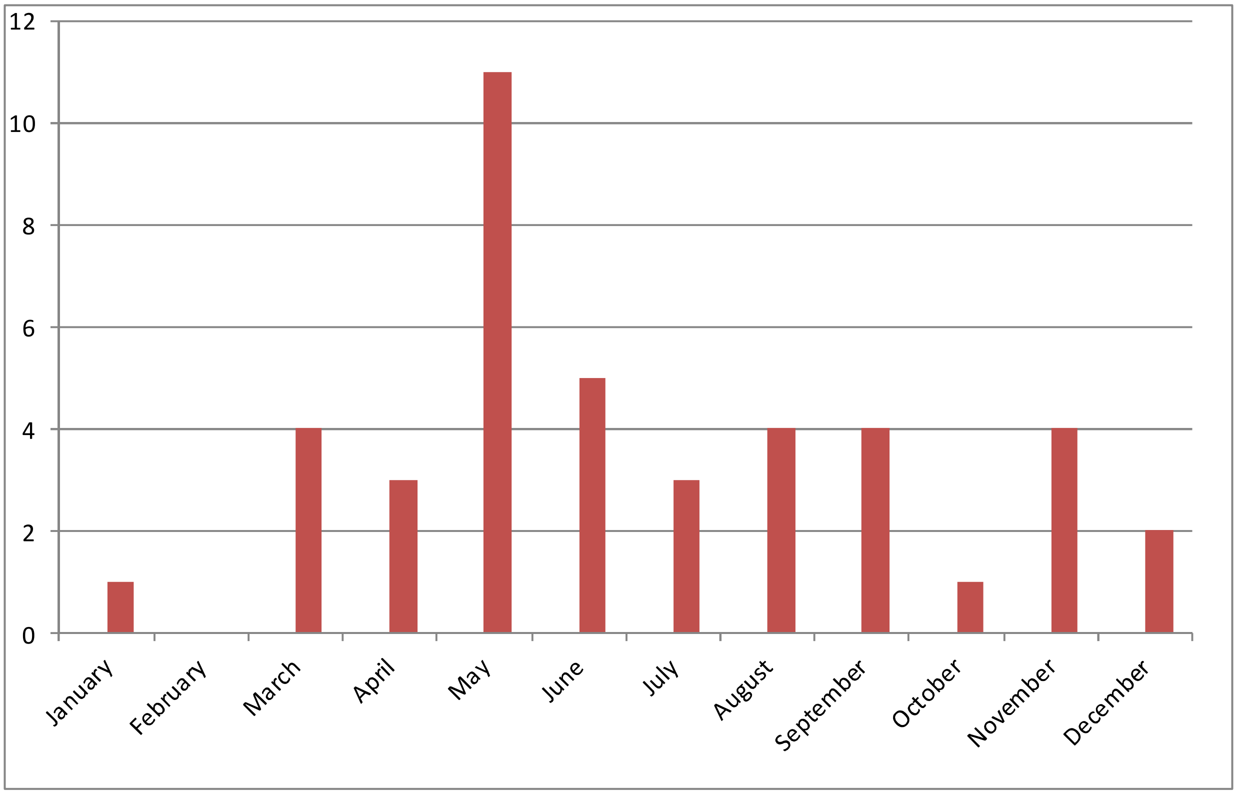

Figure 2. Flash Flood Events frequency per months from October 2007 through December 2013.

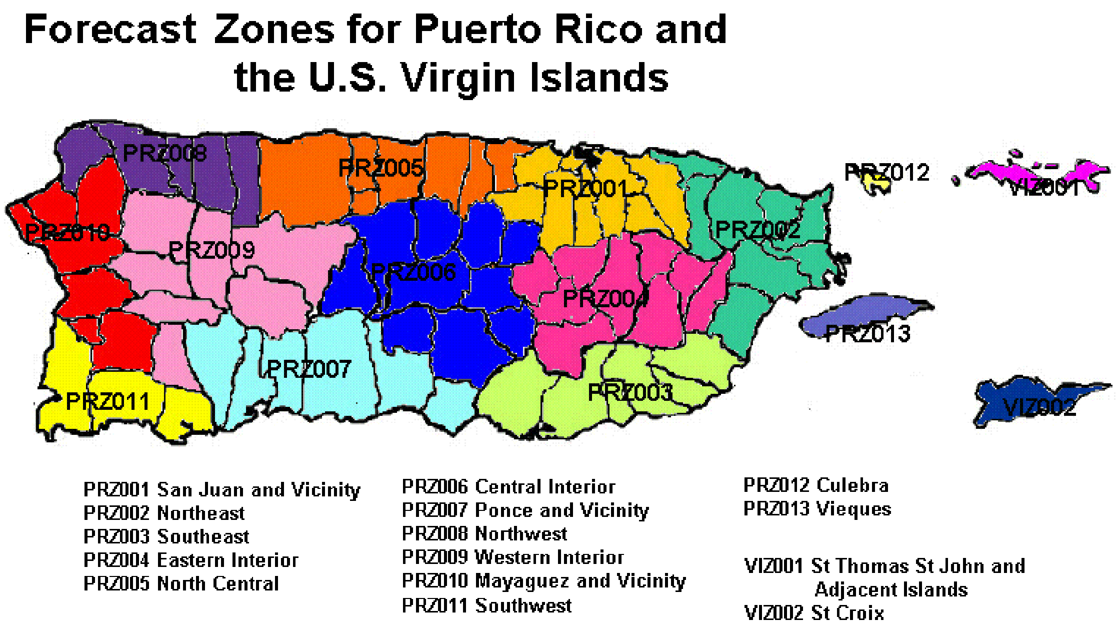

Figure 3. Forecast Zones for Puerto Rico and the U.S. Virgin Islands.

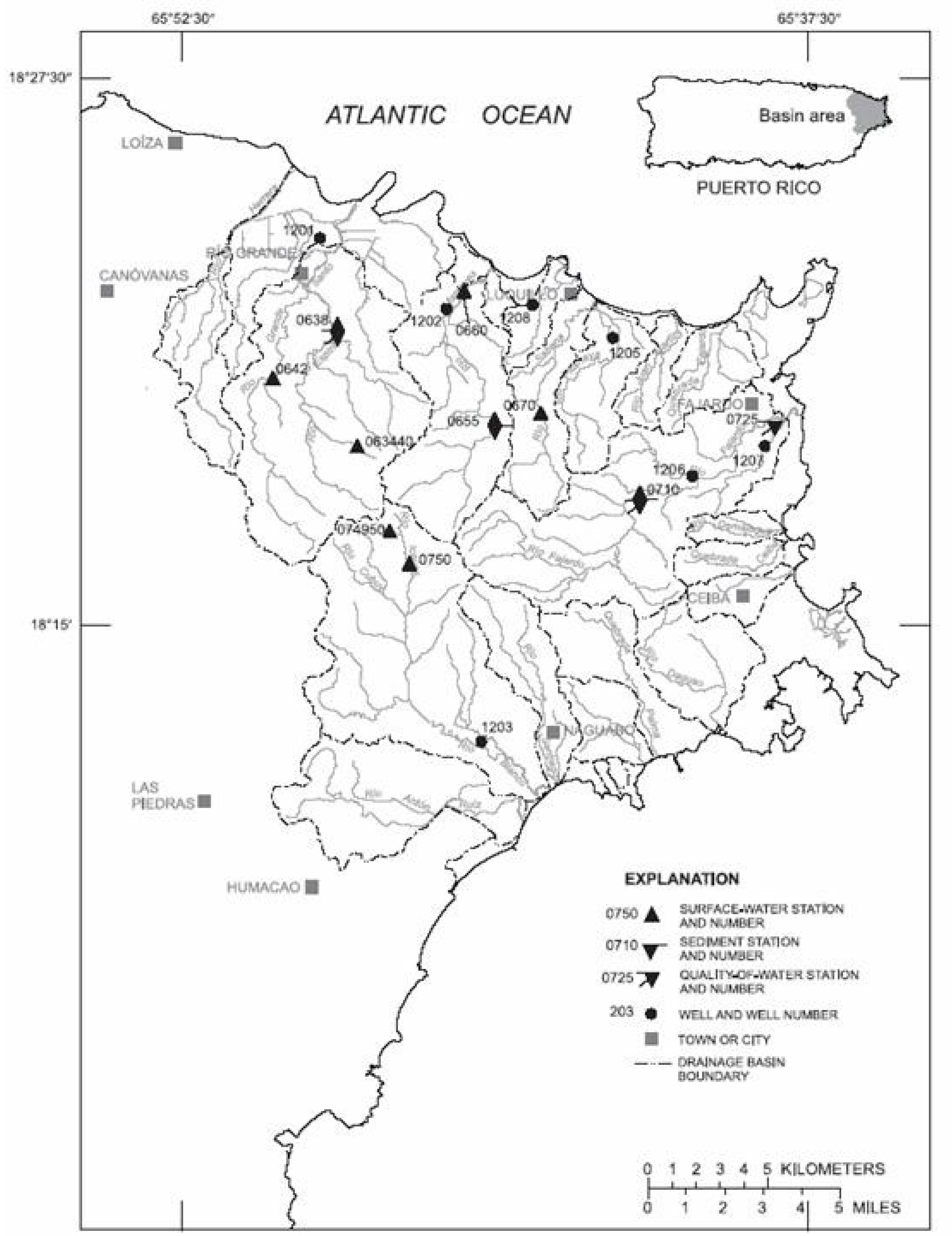

Figure 4. Northeast Puerto Rico basins.

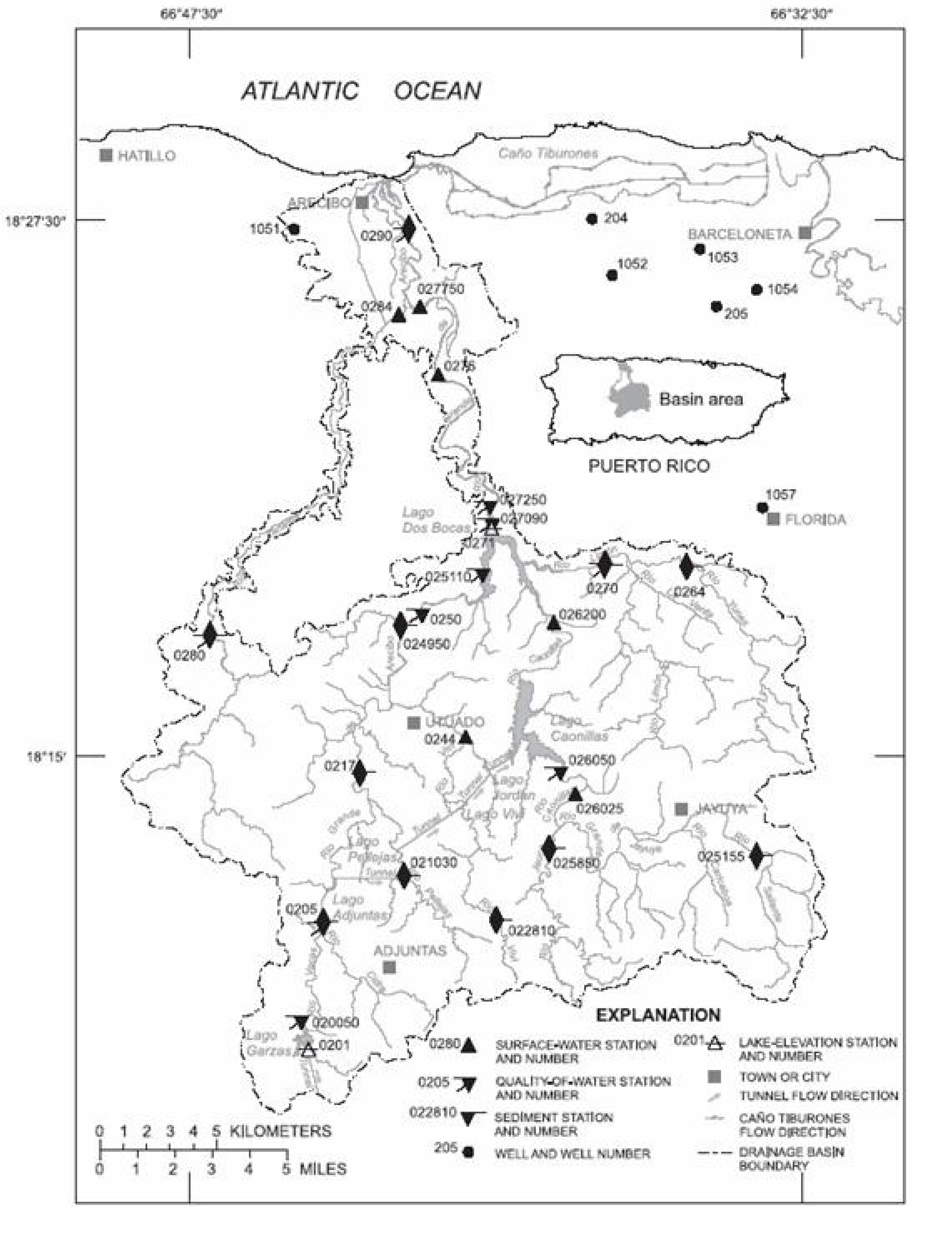

Figure 5. Rio Grande de Arecibo Basin.

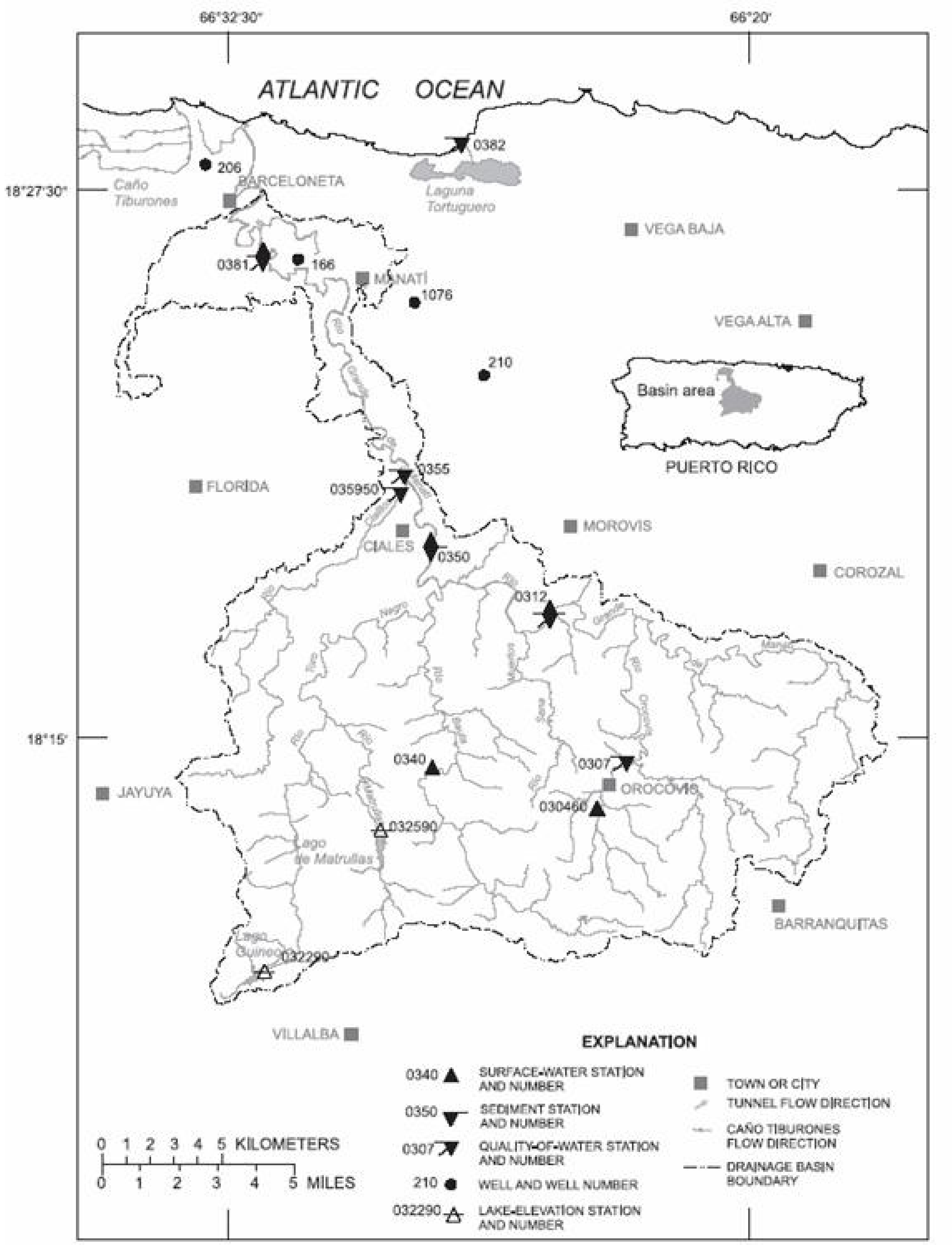

Figure 6. Rio Grande de Manatí basin.

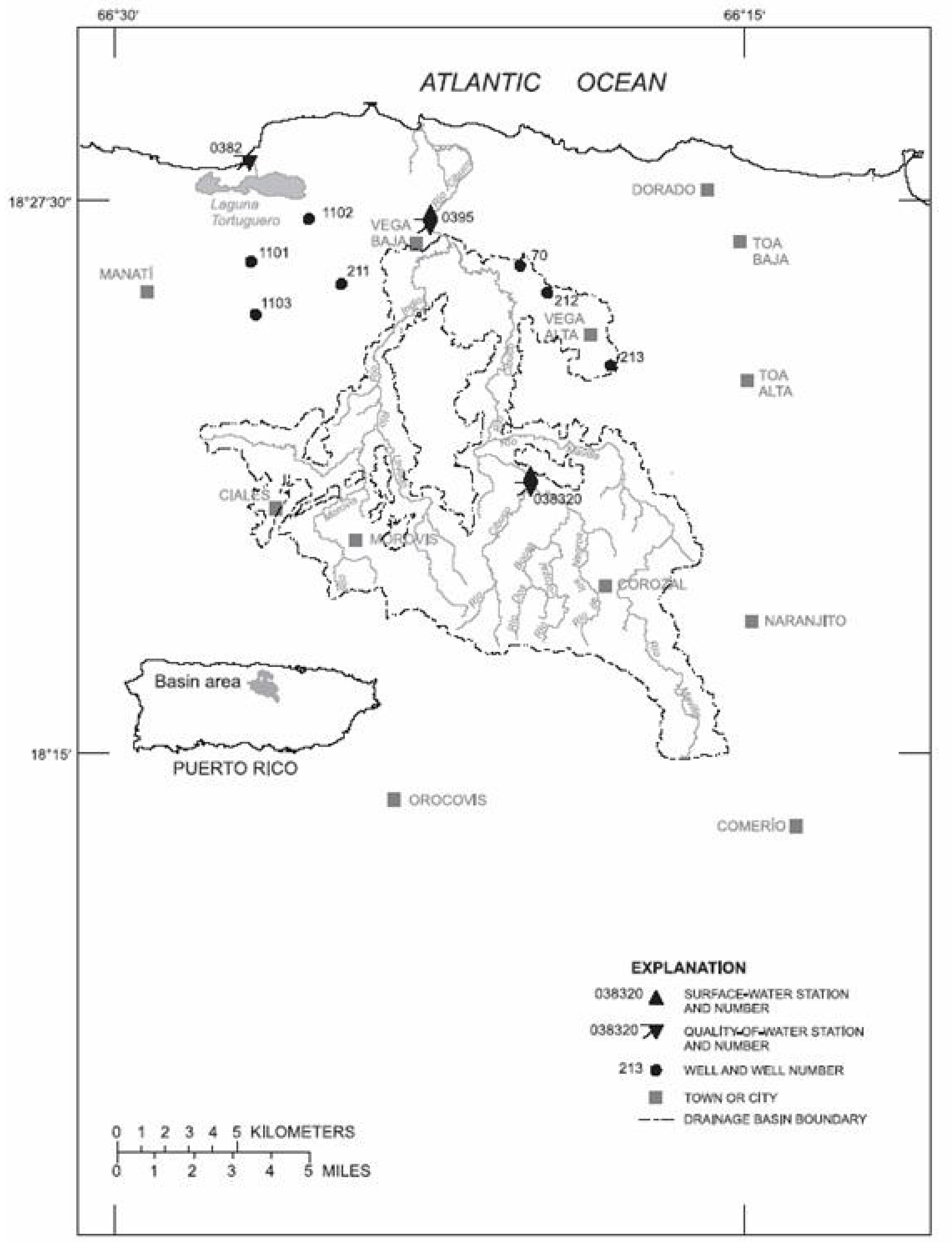

Figure 7. Rio Cibuco basin.

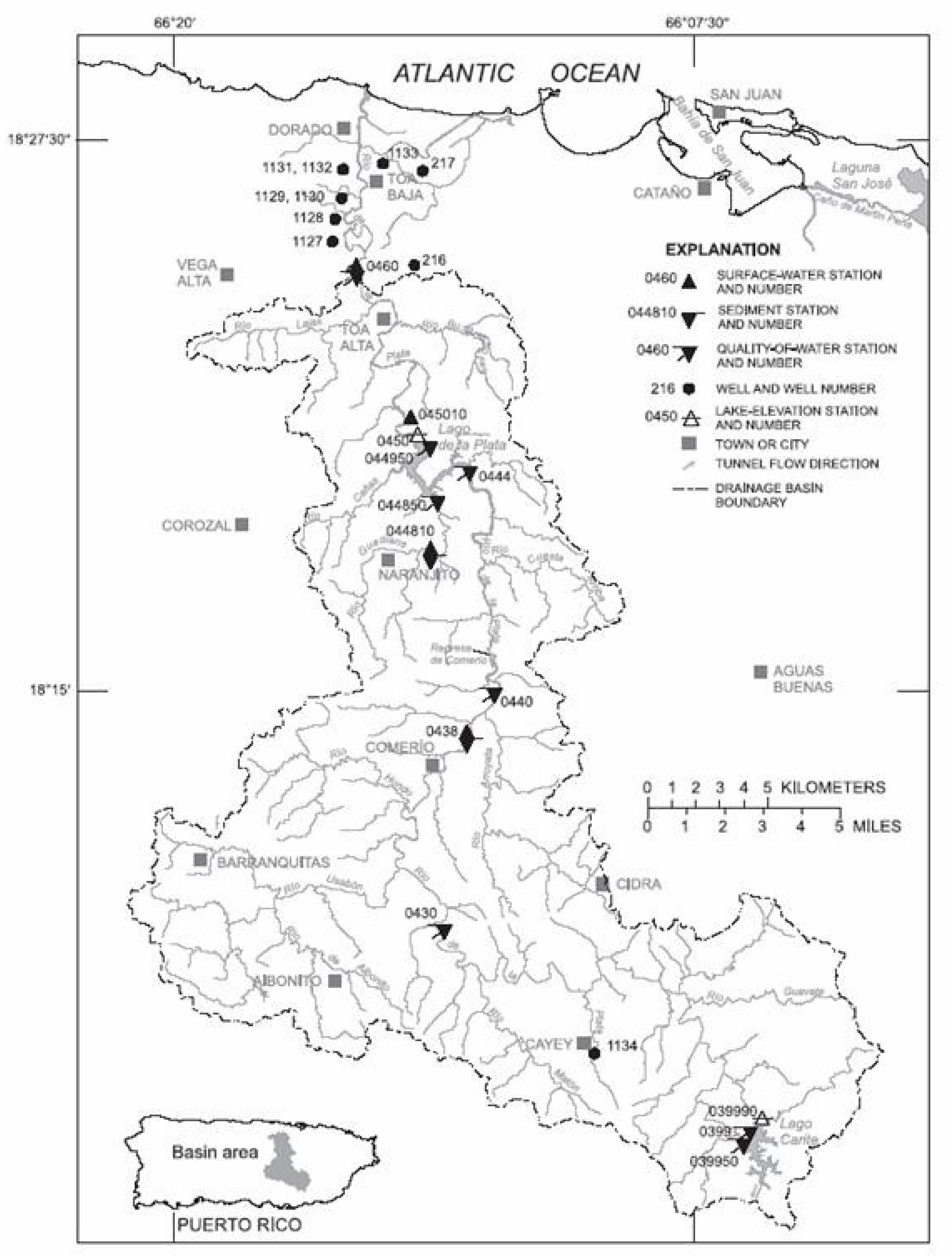

Figure 8. Rio de la Plata basin.

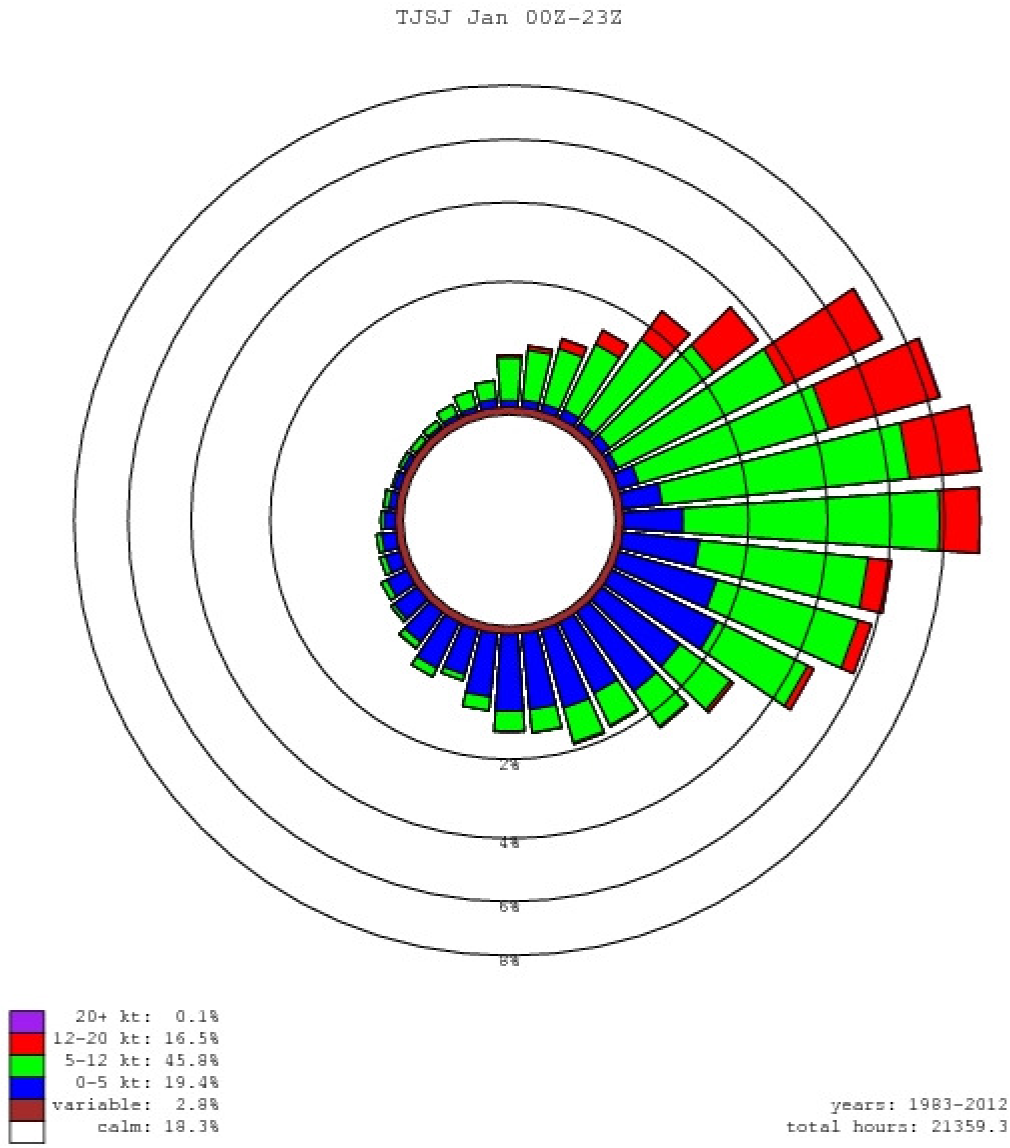

Figure 9. Wind rose for TJSJ (San Juan airport) for January. The wind rose is from 1983-2012 period.

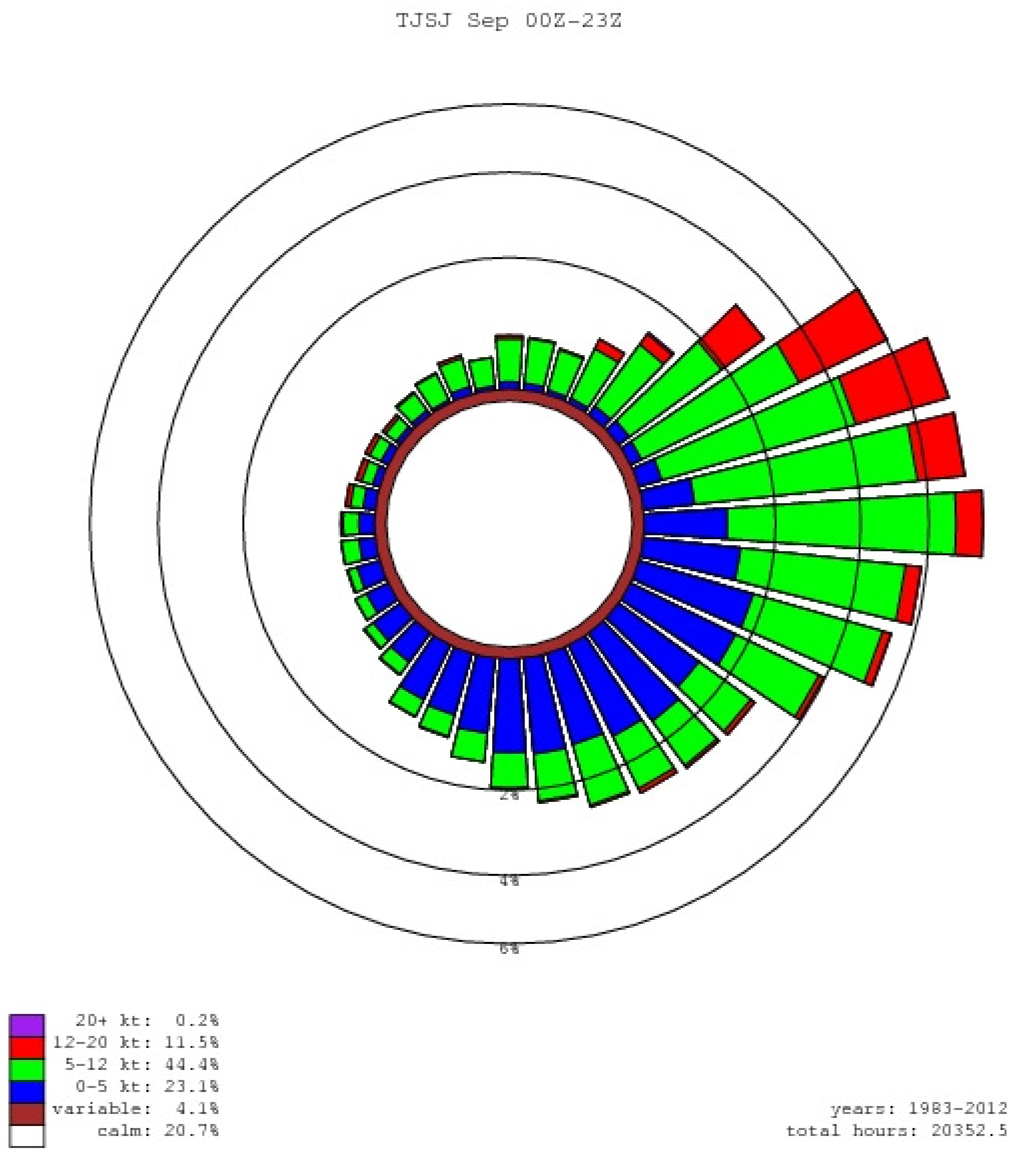

Figure 10. Wind rose for TJSJ (San Juan airport) for September. The wind rose is from 1983-2012 period.

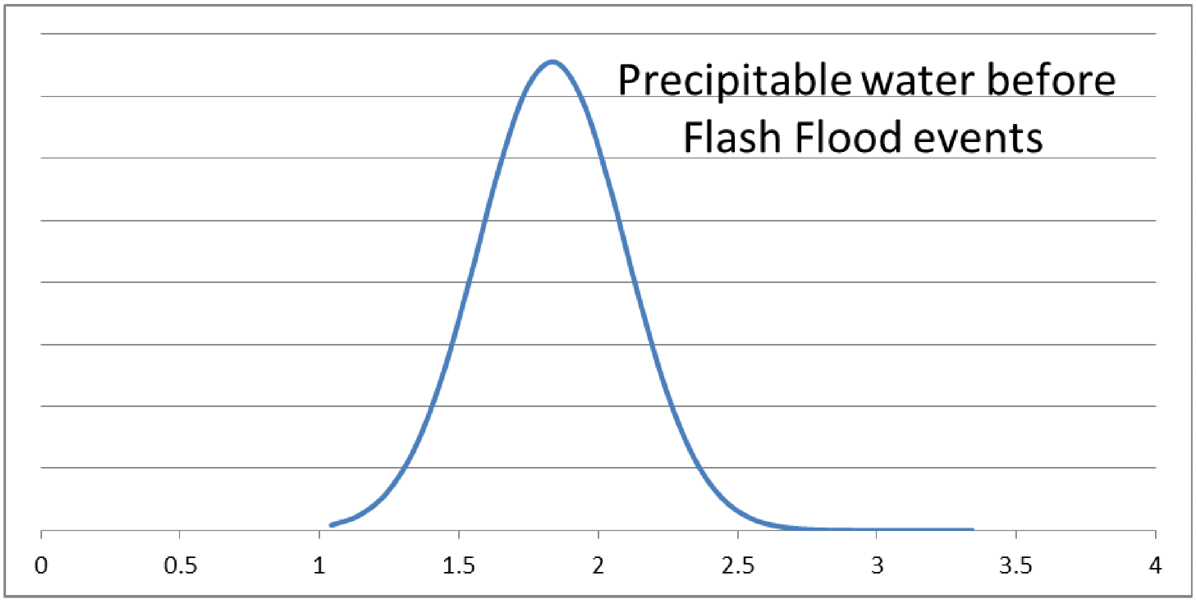

Figure 11. Precipitable water value curve. PWAT mean is 1.83 inches.

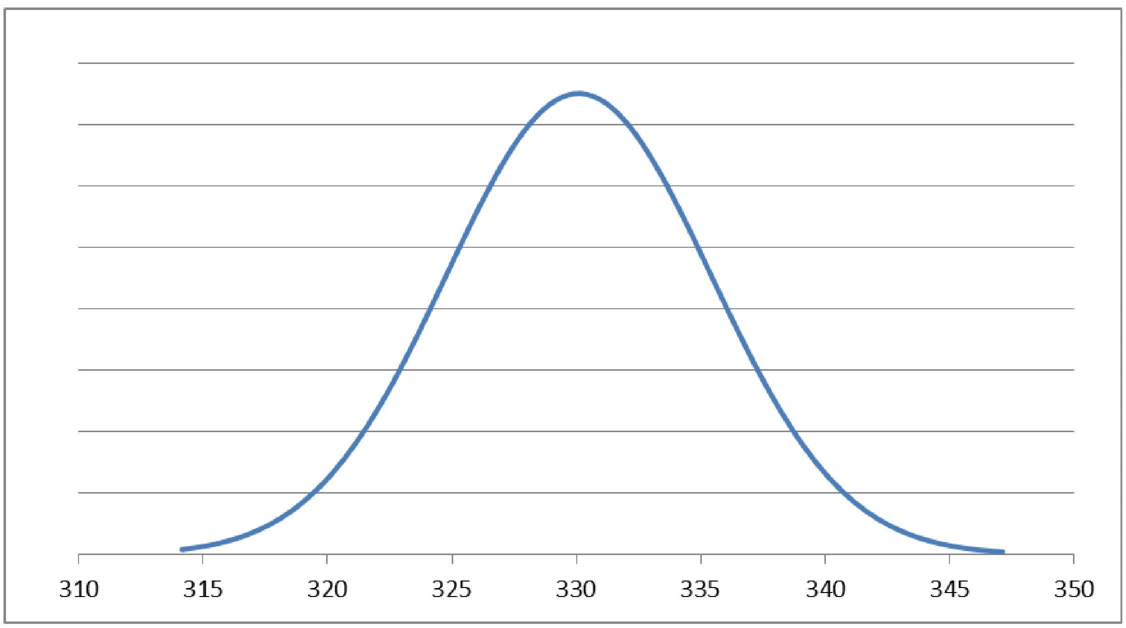

Figure 12. Theta E value curve. Theta-E mean is 330.1K prior to flash flood occurrence.

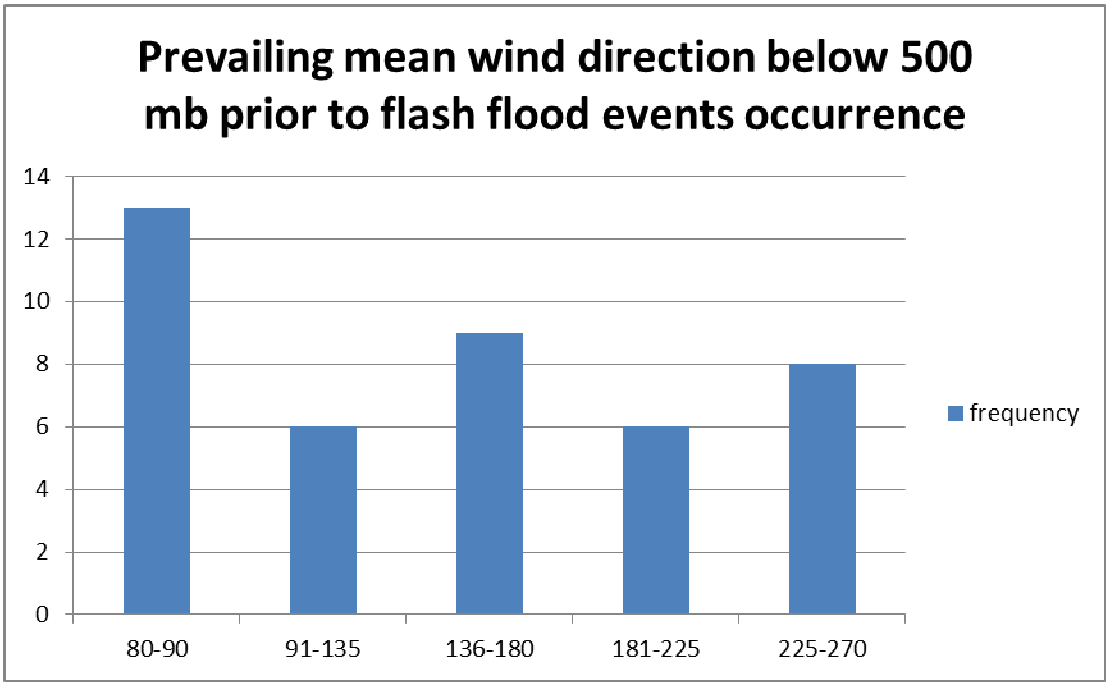

Figure 13. Prevailing mean wind direction frequency below 500 mb level prior to flash flood occurrence.

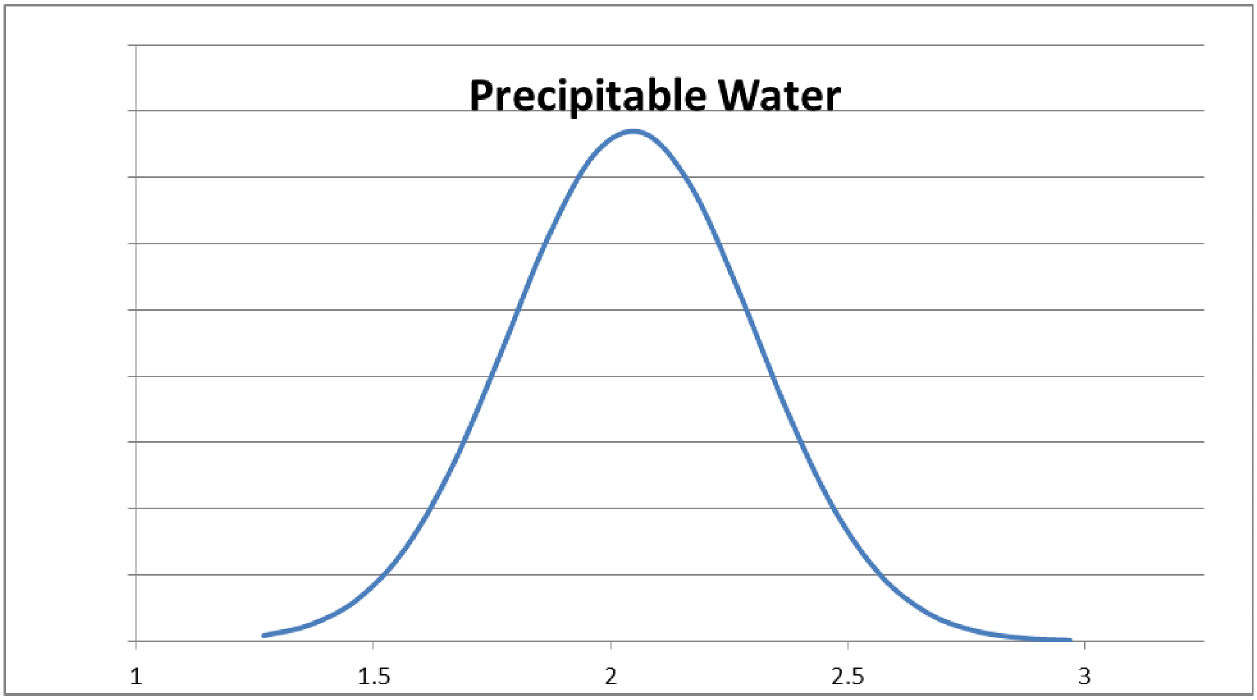

Figure 14. Precipitable Water value curve. Mean PWAT values is 2.05 inches.

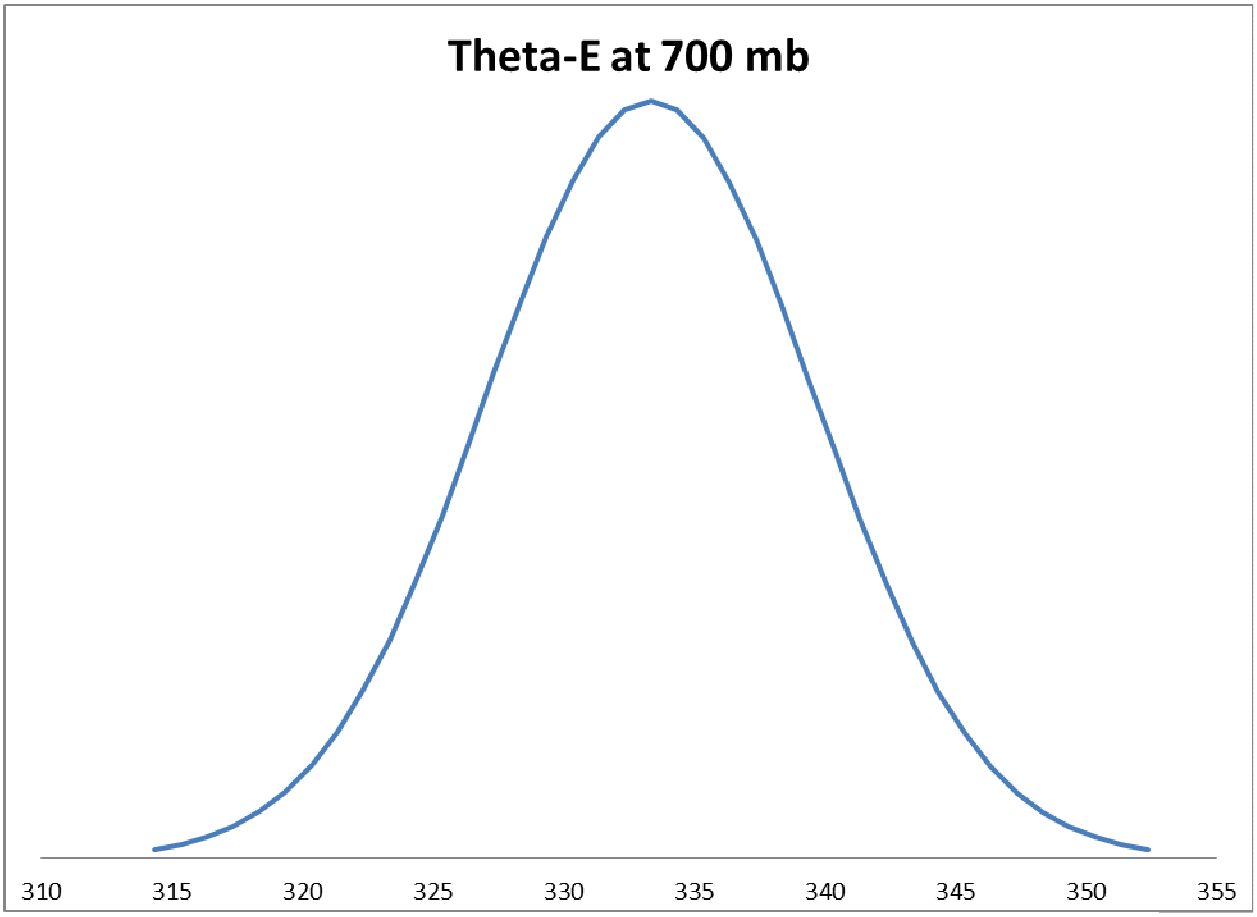

Figure 15. Theta-E value curve. Theta-E mean is 333.3K.

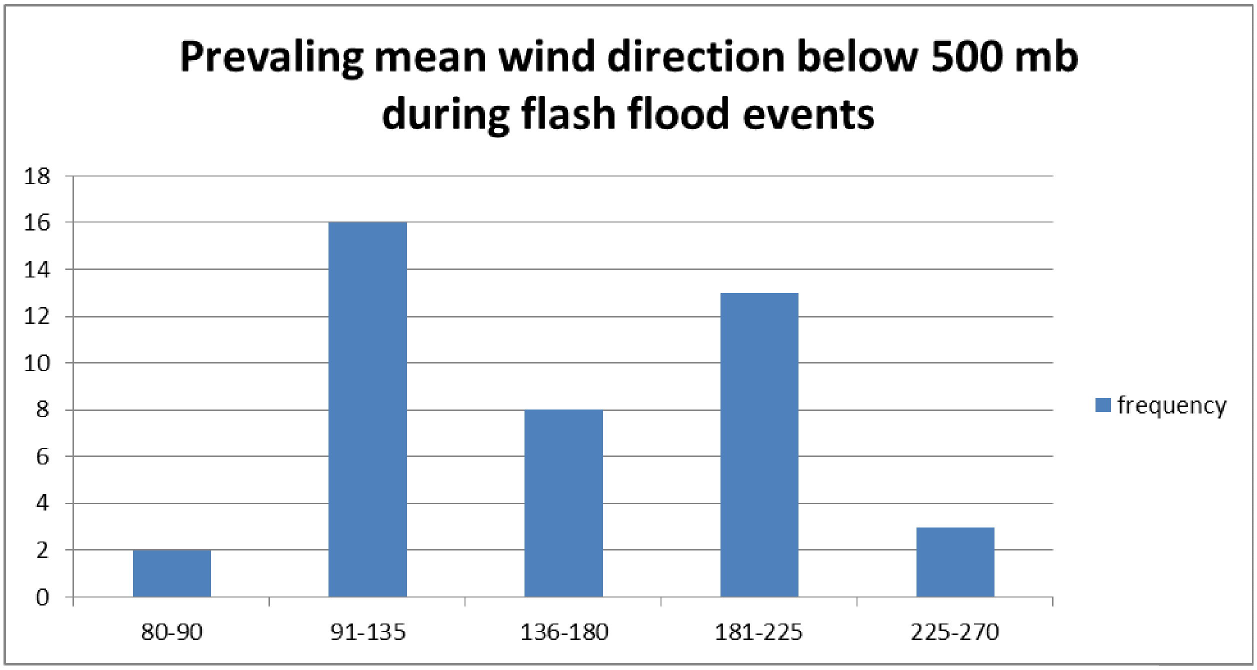

Figure 16. Prevailing mean wind direction frequency below 500 mb level during flash flood events.

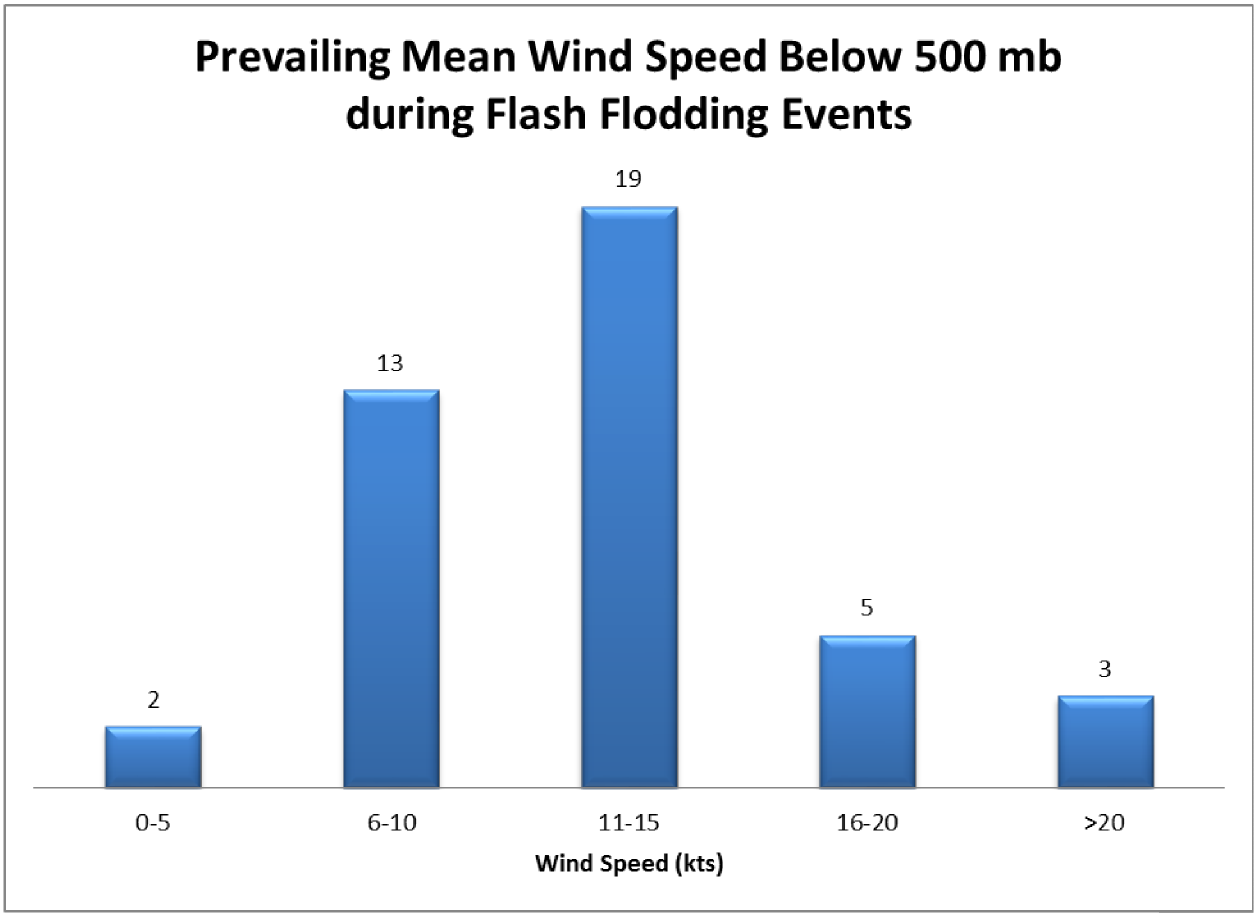

Figure 17. Prevailing wind speed frequency below 500 mb during Flash Flood events.

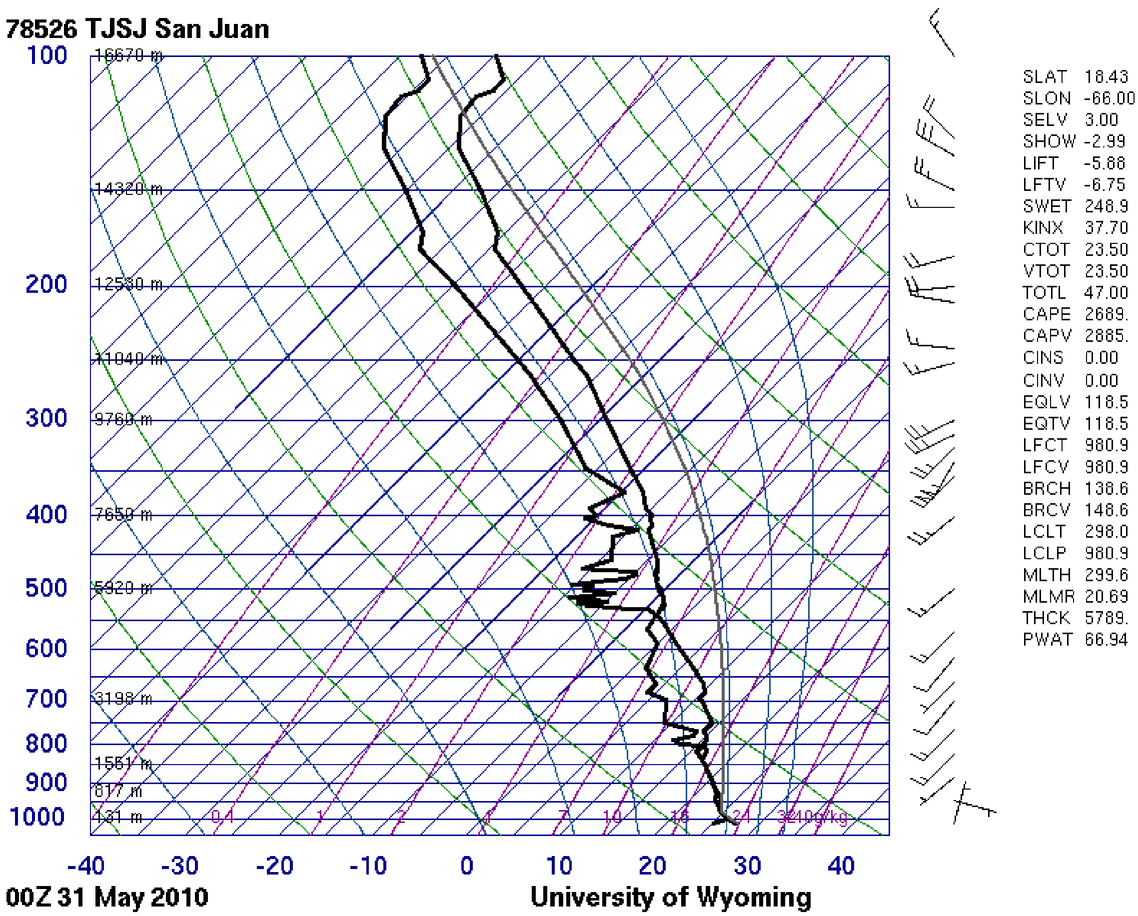

Figure 18. May 31, 2010 TJSJ sounding, showing precipitable water values of 66.94 mm (2.64 inches). Flash flooding occurred this day on North Central Puerto Rico.

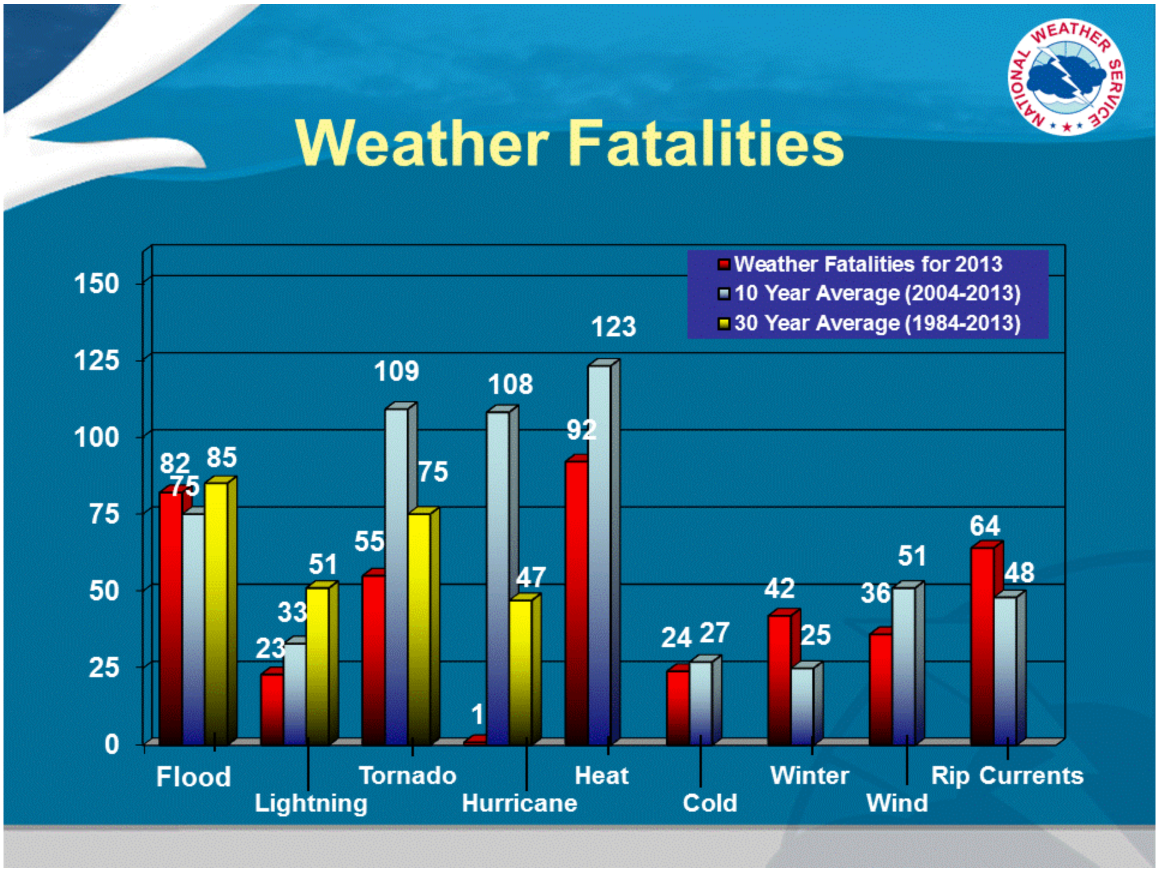

Figure 19. Weather Fatalities in the United States. Flood fatalities are the first column to the left.

8.2 Tables

Puerto Rico Zones (Table 2)		Number of cases
1	San Juan and vicinity	6
2	Northeast	12
3	Southeast	6
4	Eastern Interior	5
5	North Central	10
6	Central Interior	0
7	Ponce and vicinity	2
8	Northwest	0
9	Western Interior	1
10	Mayaguez & vicinity	0
11	Southwest	0
12	Culebra	0
13	Vieques	0

Table 1. Number of cases divided by forecast zones.

Precipitable Water	Number of cases
1	0
1.1	0
1.2	1
1.3	0
1.4	0
1.5	1
1.6	0
1.7	1
1.8	6
1.9	5
2	7
2.1	7
2.2	6
2.3	4
2.4	1
2.5	2
2.6	1

Table 2. PWAT values frequency in Flash flooding events.

Theta-E	Numbers of Cases
325-330 K	6
330-335 K	20
335-340 K	11
340-345 K	5

Table 3. Theta-E Frequency in Flash flood events.

Events	PW	Theta-E	Wind Direction(in degrees)	Wind Speed
Non-Flash flooding	1.81	330	156	13
Flash flooding	2.05	333	151	12

Table 4. Comparison between Flash flood events vs. non-flash flood events.

Year	January	February	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Totals
2008	0	0	0	0	2	0	0	10	53	12	2	0	79
2009	0	5	3	3	13	5	3	3	19	7	21	7	89
2010	3	0	3	15	37	13	16	12	1	52	18	4	174
2011	0	0	0	6	46	30	20	68	32	1	8	14	225
2012	0	0	18	0	11	2	1	8	1	8	1	0	50
2013	0	0	4	1	20	1	10	3	3	1	1	5	49
2014	0	0	0	0	6	-	-	-	-	-	-	-	6
Totals	3	5	28	25	135	51	50	104	109	81	51	30	672

Table 5. Flash Flood Warnings issued from January 2008 through May 2014. Data obtained from NWS Performance Management website. Hydrology Verification.

year	Totals
1996	26K
1997	1.5M
1998	8.58M
1999	1.47M
2000	305K
2001	205M
2002	1.33M
2003	25M
2004	320K
2005	117K
2006	4.01M
2007	172K
2008	20.2M
2009	1.43M
2010	1.46M
2011	430K
2012	1.3M
2013	57K

Table 6. Property damage in U.S. dollars over Puerto Rico in flash flood events. Data was obtained from NCDC Storm Events Database between 1996-2013.

Year	Fatalities
1996	1
1997	1
1998	3
1999	0
2000	0
2001	0
2002	2
2003	4
2004	3
2005	0
2006	0
2007	0
2008	4
2009	0
2010	4
2011	9
2012	4
2013	0
totals	35

Table 7. Fatalities in flash flood events in Puerto Rico between 1996-2013.